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Clinical and radiological outcomes of gunshot-induced femur fractures: a comparative study of monolateral external fixators and hybrid advanced ilizarov method

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ABSTRACT

Aims: Clinical and radiological outcomes, complication rates, and 10-year follow-up results of comminuted femoral open fractures resulting from firearm injuries were evaluated by comparing the Hybrid Advanced Ilizarov method (HAIM) and monolateral external fixator (MEF) of the limb reconstruction system (LRS) for treatment.

Methods: Nineteen patients (18 males, 1 female) treated with HAIM and 14 male patients treated with MEF-LRS for femoral comminuted open fractures due to firearm injuries were retrospectively analyzed. Complication rates, pin tract and deep infection rates, time to union, and the need for secondary surgeries were assessed. The Tegner activity score and Short Form-36 (SF-36) were used for comparative evaluation of functional and radiological outcomes and comfort levels with the fixator.

Results: There were no significant differences between the groups in terms of age, gender, follow-up duration, time to union, union rate, delayed union, or deep infection. No infections were detected in either group that required a change in the fixation method. There were no significant differences in radiological and functional outcomes between the groups. Significant differences were observed in terms of pin tract infections between the groups. The comfort level of MEF-LRS patients was significantly higher than that of HAIM patients.

Conclusion: In the treatment of femoral fractures due to firearm injuries in early and long-term follow-ups, similar complication rates and functional outcomes were achieved for both MEF-LRS and HAIM methods. When considering external fixator preference, MEF-LRS is a better alternative, with a lower rate of pin tract infections and higher patient comfort level.

Keywords: Femur fracture, hybrid advanced Ilizarov method, monolateral external fixator, pin tract infection

INTRODUCTION

Fractures caused by gunshot injuries often result in significant soft tissue damage and extensive fragmentation at the fracture site. Treating femoral diaphyseal fractures resulting from gunshot wounds poses a considerable challenge for orthopedic surgeons due to complications like soft tissue issues, neurovascular damage, and a heightened risk of infection.[1] The femur is particularly susceptible to damage, accounting for forty percent of lower extremity gunshot injuries. Contrary to popular belief, the heat generated by the firearm during discharge does not guarantee a sterile fracture environment.[2,3] In fact, the bullet, along with skin and clothing fragments, can contaminate the fracture site and introduce infection sources.

While minor gunshot wounds with acceptable infection rates and reasonable healing times have been successfully treated using simple debridement and early intramedullary nailing (IMN)[1,4,5] there is no established treatment protocol for contaminated injuries. Given that many of these injuries result in complex fractures, external fixators (EFs) provide a suitable treatment option. Depending on the fracture type and extent of soft tissue damage, hybrid advanced Ilizarov method (HAIM) or monolateral external fixation (MEF) may be favored. Recent advancements in MEF designs have improved application ease and patient adherence compared to traditional circular fixators.[6]

This retrospective study aims to assess the outcomes of HAIM and MEF in patients with open femoral fractures resulting from gunshot injuries.

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METHODS

The study was carried out with the permission of Gazi Yaşargil Training and Research Hospital Clinical Researches Ethics Committee (Date: 12.06.2022, Decision No: 2022/492). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Between March 1998 and October 2019, our institution treated forty-five patients with monolateral external fixation (MEF) using the Orthofix Limb Reconstruction System (Orthofix, Verona, Italy) in (**Figure 1**) or the hybrid advanced Ilizarov method (HAIM) in (**Figure 2**).[5] In 2019, we followed up with 33 of these patients (14 with MEF, 19 with HAIM) because 12 patients could not be reached for long-term follow-ups. These individuals underwent physical examinations and X-ray evaluations to assess knee and hip joint mobility, identify potential recurrent fractures, and detect chronic osteomyelitis or pin site issues in the fracture area.

Medical records were reviewed to classify fractures according to the Gustilo-Anderson and The Association for the Study of Internal Fixation (AO/ASIF) classification. The type of fixator employed, and the injury type were recorded. All patients received a tetanus toxoid vaccine, while prophylactic treatment consisted of intravenous first-generation cephalosporin (cephazolin 50 mg/kg/day), metronidazole (20 mg/kg/day), and aminoglycoside (2.5 mg/kg/day) for five days. Angiography was conducted for patients with impaired peripheral pulses or undetectable pulses by Doppler ultrasonography, with vascular repair performed as necessary.[7]

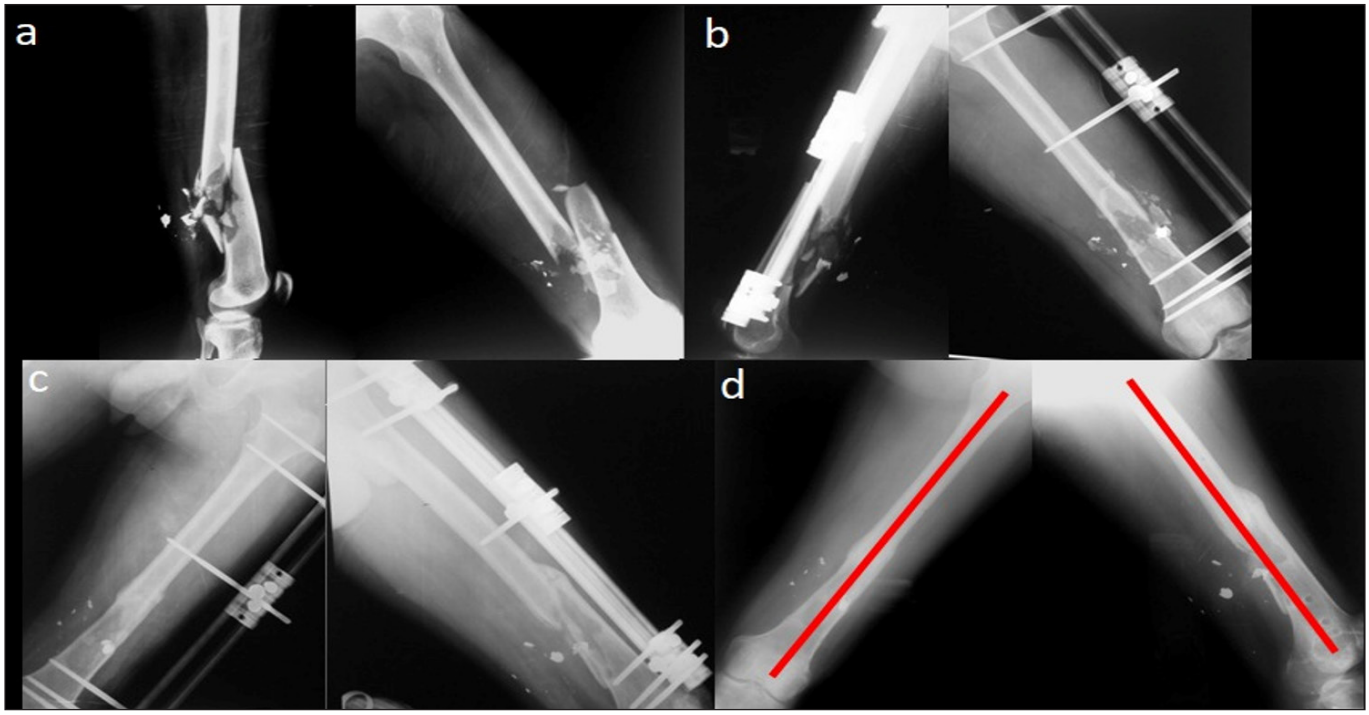

Figure 1. a) Two-way X-Ray Graph of The Femur Fracture, **b)** Two-way X-Ray Graph After Monolateral External Fixators Application, **c)** Two-way X-Ray Graph of After bone-healing, **d)** X-Ray Graph of the Removed the Fixator

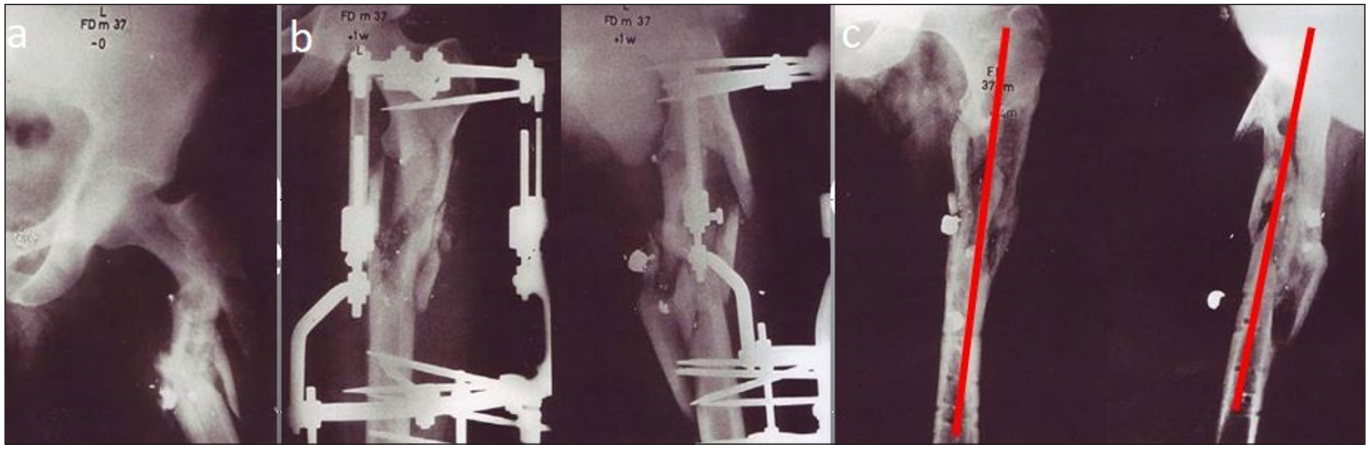

Figure 2. a) X-Ray Graph of The Femur Fracture, **b)** Two-way X-Ray Graph After Hybrid Advanced Ilizarov Application, **c)** Two-way X-Ray Graph of After the removed fixator and bone-healing

Surgical and treatment complications were documented, and radiographic measurements were taken before surgery and at the final follow-up. Radiographs were assessed for lower limb alignment and union. The duration of external fixator usage was calculated. Outcome evaluations included the Tegner activity score, Short Form-36 (SF-36), and criteria proposed by Thoresen.[8,9]

Postoperatively, wound care involved twice-daily cleaning using hydrogen peroxide or povidone-iodine solutions for wire tract hygiene during the first week. Daily care was administered to patients without wire tract infections. Infection severity guided treatment for cases with observed infections, ranging from local care for mild infections to wire or nail removal, curettage, and antibiotic therapy for more severe cases.

To prevent quadriceps atrophy and knee motion limitations, isometric and passive stretching exercises commenced on the first day post-surgery. Mobilization started on the second day for both groups, with weight-bearing allowed based on pain tolerance. Patients utilized two crutches for six weeks post-surgery and transitioned to a single crutch after the sixth week. By the end of the second month, all patients could walk unaided.

Fracture union progress was monitored using X-rays taken every 30 days, with bridging callus presence across at least three cortices indicating union. Pathological motion was assessed fluoroscopically after EF removal. Fixator removal occurred in outpatient clinics or operating rooms under general anesthesia, considering patient well-being. After EF removal, a brace protected the operated leg for six to eight weeks.

Statistical Analysis

Analysis employed the NCSS 2007 software, using descriptive statistics (mean, median, standard deviation, ratio, frequency, minimum, maximum), Student's t-test for normally distributed quantitative data comparisons, Mann-Whitney U test for non-normally distributed variables, and Fisher-Freeman-Halton exact test for qualitative data comparisons. Significance was established at $p<0.01$ and $p<0.05$ levels.

RESULTS

The study involved a cohort of 33 patients, comprising 32 males and 1 female, with an average age of 31.97 years (range: 18 to 49). The follow-up period averaged 10.2 years (range: 10 to 12) and 9.86 years (range: 10 to 11) for the MEF and HAIM groups, respectively. Among the fractures, 18% were located in the distal third of the femur, 76% were diaphyseal, and 6% were in the proximal third. Gunshot-induced fractures were predominantly caused by low-velocity (88%) and close-shot (12%) incidents. Vascular and neurological injuries were encountered in only one patient (3%) (Table 1).

Long-term follow-up revealed satisfactory knee range of motion for all patients, although patients treated with MEF experienced easier knee motion. The average fixator duration was 166.81±23.55 days. All fractures healed without requiring a second surgery, and no instances of recurrent fractures, neurovascular deficits, or compartment syndrome were observed.

Table 1. Descriptive characteristics of the groups

	MEF (n=14)	Ilizarov (n=19)	[a]p
	Mean±SD (Median)	Mean±SD (Median)	
Age (yrs.)	30.36±7.95	33.58±7.26	[b]0.235
External fixator time (days)	156.43±18.44	174.47±27.33	[b]0.041*
Follow-up time (months)	49.86±10.20 (53.5)	50.21±4.84 (50)	0.553
Time to union (days)	147.14±20.16	158.16±21.81	[b]0.149
Preoperative wait time (months)	4.07±0.83 (4)	4.11±1.45 (4)	0.760
Surgical time (minutes)	70.36±11.68 (65)	161.53±18.49 (160)	<0.001†
Fluoroscopy time (minutes)	0.77±0.23	3.63±0.79	[b]<0.001†
	n (%)	n (%)	[c]p
AO fracture type			0.791
B3	6 (42.9)	7 (36.8)	
C1	1 (7.1)	3 (15.8)	
C3	7 (50.0)	9 (47.4)	
Gustilo-Anderson fracture type			0.999
Type 3A	12 (85.7)	16 (84.2)	
Type 3B	2 (14.3)	2 (10.5)	
Type 3C	0 (0.0)	1 (5.3)	

aMann-Whitney U test, bStudent's t-test, cFisher-Freeman-Halton exact test, *p<0.05, †p<0.01

Over a 10-year follow-up, no patients experienced re-fractures, and physical examinations and X-rays detected no indications of chronic osteomyelitis or pin site infection in the femoral fracture area. Significantly higher VAS, SF-36, and Tegner activity scores were noted in the MEF group. The two groups exhibited no statistically significant differences in varus/valgus, ante/recurvation angle, mechanical axis deviation, knee extension/flexion deficit, and age.

In terms of pin side infections, noteworthy distinctions were found between the groups. The MEF group required removal of only one infected Schanz pin from the trochanteric region, while the HAIM group necessitated removal of four Schanz pins from the trochanteric region and one from the condylar region, followed by antibiotic treatment. No infections prompted a change in fixation method in either group (Table 2).

Discomfort with the fixator was reported by one MEF patient and three HAIM patients, with extreme discomfort rated at 5 points. Complications were generally manageable without lasting consequences. Limb shortening exceeding 2 cm occurred in two HAIM patients who sustained refractures from falls downstairs. In the MEF group, one patient experienced fracture recurrence with minor trauma following fixator removal.

DISCUSSION

Regrettably, gunshot-induced fractures have increased in prevalence in many regions due to escalating personal armament.[10] As with all open fractures, the goals of treating femoral open fractures due to gunshot injuries include preventing infection, promoting fracture healing, and restoring limb functionality.[11-13] External fixators (EFs) are an effective treatment choice for these fractures, considering their common fragmentation, contaminated nature, and challenges posed by early surgical intervention.[14] A notable outcome of this study is the congruence in treatment results and complications encountered between the two distinct fixation techniques.

Patient acceptance and wire tract infections represent major drawbacks of external fixation methods.[8,9,15-17] Wire tract infections, occurring in approximately 95% of cases, are the most frequent complications of external fixators.[7,8,17,18] Monolateral fixators may garner greater patient acceptance due to fewer pins and wires, whereas hybrid systems integrate advantages of both methods for enhanced patient comfort.[15-17] Hybrid systems involving arches and Schanz nails in the hip region and wire-nail combinations in the distal femur have shown promise in enhancing hip and knee mobility.[19]

Table 2. Clinical results of the groups

	MEF (n=14)	Ilizarov (n=19)	[a]p
	Mean±SD (Median)	Mean±SD (Median)	
Pin tract infection	1.50±0.52 (1.5)	2.95±0.23 (2)	0.010*
Varus/valgus	3.50±2.56 (4)	4.79±3.55 (4)	0.287
Ante/recurvatum	5.86±3.11 (5)	6.53±5.12 (5)	0.999
Rotation/internal	2.29±4.86 (0)	3.63±6.77 (4)	0.602
Rotation/external	-2.29±4.86 (0)	-3.63±6.77 (-4)	0.602
Shortness (cm)	0.53±0.64 (0.35)	1.05±0.81 (0.8)	0.035*
Knee flexion (degrees)	125.00±11.09 (127.5)	118.68±14.89 (125)	0.077
Loss of extension in the knee (degrees)	3.29±3.83 (2.5)	4.00±3.86 (5)	0.602
Knee ROM at the 3rd month	96.07±6.84 (95)	89.47±7.43 (90)	0.017*
Knee ROM at the 6th month	125.00±11.09 (127.5)	118.68±14.89 (125)	0.077
VAS post-op	6.00±1.11 (6)	6.63±1.16 (7)	0.174
VAS follow-up	0.71±1.14 (0)	1.95±1.78 (1)	0.021*
SF-36	92.50±6.56 (94.5)	82.05±12.06 (89)	0.001†
Tegner activity score	5.14±1.46 (6)	4.11±1.52 (5)	0.035*
Level of patient comfort	2.29±0.91 (2)	4.47±0.51 (4)	<0.001†
	n (%)	n (%)	[b]p
Pain			0.726
None	11 (78.6)	11 (57.9)	
Mild	2 (14.3)	5 (26.3)	
Moderate	1 (7.1)	2 (10.5)	
Severe	0 (0.0)	1 (5.3)	
Thoresen scoring			0.726
Poor	0 (0.0)	1 (5.3)	
Fair	1 (7.1)	2 (10.5)	
Good	2 (14.3)	5 (26.3)	
Excellent	11 (78.6)	11 (57.9)	

aMann-Whitney U test, bFisher-Freeman-Halton exact test, *p<0.05, †p<0.01

Pain significantly impacts patient quality of life and hampers compliance with physical rehabilitation. Pain sources include wires and nails attaching muscles and wire tract infections.[7,8,16] The MEF technique, avoiding trans osseous wires and employing fewer nails, notably reduces pain and improves joint mobility.

Pin tract infection frequency varies based on fixator design, pin location, tension, and surgical technique. The risk of infection is notably lower in gunshot-induced fractures treated with external fixators compared to other methods. External fixators provide mechanical stability against various forces and minimize postoperative complications such as reduction loss, angular deformities, and shortening.[20]

Ilizarov's external fixation offers the advantage of addressing technical errors without requiring re-surgery. Although limb shortening rates range from 8% to 16% with external fixation, our study achieved adequate femoral length in 94% of cases. Proper initial reduction contributes to avoiding femoral shortening.[1,10,21]

While knee flexion loss is often attributed to external fixators, it's primarily associated with fracture location, soft tissue damage, and lower extremity injuries. Physiotherapy initiated promptly after stabilization mitigates motion restrictions. In our study, no significant intergroup differences were observed in knee motion[8,16]

CONCLUSION

Our data suggest comparable healing time, joint range of motion, and angular deformity outcomes between MEF and HAIM treatment groups. MEF may offer an alternative to HAIM, characterized by reduced patient complaints, lower wire tract infection rates, and enhanced patient comfort 22 MEF's design for deformity surgery provides adequate stabilization and mitigates many complications seen in external fixators. As a low-infection-rate option with similar functional and radiological outcomes to intramedullary fixation methods, MEF holds promise. Further studies comparing MEF with intramedullary fixation methods are warranted for a more comprehensive understanding.[21-23]

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Gazi Yaşargil Training and Research Hospital Clinical Researches Ethics Committee (Date: 06.12.2022, Decision No: 2022/492).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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